

Slovenian experiences with mini roundabouts and assembled roundabouts

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ABSTRACT

This article describes and analyzes the Slovenian experience with assembled roundabouts and mini roundabouts. Unlike other types of modern roundabouts that we have had in Slovenia for more than 20 years, the first mini roundabout was constructed in 2002, with the first assembled roundabout in 2006. Notwithstanding the relatively short period of time, during that period several mini roundabouts as well as assembled roundabouts were constructed in Slovenia.

We have actively monitored the processes of implementing mini roundabouts and assembled roundabouts from the beginning, from the first implemented roundabouts to today. This paper presents and analyzes the experiences we have gained during this time.

We analyze the individual characteristics of Slovenian assembled roundabouts, like conditions and locations of appropriate usages of the assembled roundabouts, time periods of usage as a temporary solution, processes prior to the construction, elements for assembled roundabout construction, and also some design considerations for implementing them.

Some of the characteristics of mini roundabouts differ from "normal" single lane roundabouts. Based on our experience gained, it can be concluded that at during mini roundabouts design it is very important to choose the proper design parameters, the design and construction elements should be adjusted, and the splitter island's design is especially important from the driving lines point of view.

Based on the results of a traffic safety analysis of mini roundabouts constructed in Slovenia, we observed traffic accidents that had occurred at mini roundabouts 3 years prior to the reconstruction of intersections to the mini roundabouts and 3 years after them. It can be seen that the number of traffic accidents decreased by approximately 7 times.

INTRODUCTION

In the Republic of Slovenia, modern roundabouts have become more and more appealing for both designers and investors, especially over the last 20 years. Our deep interest in modern roundabouts started two decades ago, before which Slovenia had practically no significant experiences with roundabouts and their advantages as traffic control systems. After 20 years since the first wave of modern roundabouts in Slovenia, there are currently more than 500 roundabouts (Mini, Single-lane, Multi-lane, and Turbo) installed all over the country. It is admirable that both the roundabouts' designers and contractors have carried out their work professionally and with a high degree of care and skill when considering that there was (a) a chronic lack of professional literature on roundabouts (b) an excess of professional literature, manuals, and guidelines from other countries (c) a lack of our own guidelines for roundabouts (d) no data regarding the number as well as the consequences of local traffic accidents. The process of introducing roundabouts into the Republic of Slovenia was spearheaded by a number of stakeholders. The key stakeholders included the traffic police, the media, and driving schools. The media especially played an important role by providing information to the largest number of users namely; PCU drivers, pedestrians, as well as cyclists. After the initial enthusiasm over the introduction of the first few roundabouts into Slovenia had subsided, questions concerning the justification of their installations and actual traffic safety surfaced. When considering that roundabouts in Slovenia were at the time a new phenomenon (with the exception of a few earlier examples), the concerns raised were completely understandable. Furthermore, there was no assurance that roundabouts in Slovenia would prove themselves appropriate, as they had abroad (in Holland, Germany and the United Kingdom). Today in Slovenia we have roundabouts of varying types; mini roundabouts, standard one-lane roundabouts, two and three-lane roundabouts, double roundabouts, assembled roundabouts, turbo-roundabouts and signalized turbo-roundabout, of which approx. 70% are on state roads, and 30% on municipal and private roads [1].

The assembled (temporary) roundabout is a temporary design solution placed within the dimensions of the existing "standard" three- or four-arm intersection and constructed with the use of elements, traffic signs, road markings and equipment pursuant to traffic safety requirements, and intended for improving traffic capacity and/or traffic safety. Placement within the dimensions of the existing "standard" intersection implies the construction of an assembled roundabout, if possible within the boundaries of the existing intersection, i.e. "between the existing curbs". The construction of an assembled roundabout does not envisage considerable displacement of the existing intersection curbs, major construction works, nor any other similar complex undertaking in terms of finance and construction.

Mini roundabouts, on the other hand, are not such a novelty. For example, in the UK the modern concept of a mini-roundabout had already been introduced by the early 1970`s. Mini roundabouts are well-known as roundabout design solutions for the means of improving capacity and reducing delays at existing junctions where there is limited space for introducing other forms of control (or a typical one lane roundabout). It is worth mentioning that mini roundabouts today are also recognized as traffic calming measure within build-up areas.

ASSEMBLED ROUNDABOUTS

The assembled roundabout (in some cases also called "temporary roundabout") is a temporary design solution placed within the dimensions of the existing "classic" intersection and constructed with the use of elements, traffic signalization and equipment pursuant to traffic safety requirements, and is intended for improving traffic capacity and/or traffic safety. Placement within the dimensions of the existing "classic" intersection implies the construction of a temporary roundabout, if possible within the boundaries of the existing intersection, i.e. "between the existing curbs". Construction of a temporary roundabout does not envisage considerable displacement of the existing intersection curbs, raising of the asphalt, nor any other similar complex undertaking in terms of finance and construction.

A temporary roundabout must be constructed using elements, traffic signalization and equipment compliant with applicable regulations and safety requirements. This means that the temporary solution must be comprised of the same elements used for a permanent solution (radii of proper size, central island, splitter islands, pedestrian crossings, traffic signalization, etc.), and the only difference is that these elements are prefabricated, and the traffic signalization is temporary (and the markings are yellow).

In Slovenia over the past ten years we have implemented different types of assembled roundabouts: mini assembled, one-lane assembled (Figure 1), two lane assembled and turbo assembled roundabouts (Figure 2).



FIGURE 1 First Slovenian assembled roundabout in Maribor, year 2006 [3].



FIGURE 2 Assembled turbo-roundabout in Koper, year 2012.

Conditions and locations for the appropriate usages of the assembled roundabouts

When implementing an assembled roundabout, selecting an appropriate location for the roundabout is very important. The characteristics of the roundabout should also reflect the traffic conditions; so it is necessary to carefully examine whether to remodel the existing intersection (non-signalized or signalized) to the assembled roundabout will have a positive impact on the traffic flows or not. It is necessary to be aware of the fact that the roundabout performs uninterrupted traffic flow, unlike for example the signalized intersection.

According to our observations of Slovenian assembled roundabouts we could conclude that the assembled roundabouts are suitable and recommended for the following conditions and locations:

- In places particularly prone to accidents with severe consequences;
- When driving speeds through intersections are too high;
- Where traffic conditions change (e.g., at the end of high-speed sections, entries to urban areas, motorway exits);

- Temporarily obstructed traffic flows (e.g. A construction site near the intersection);
- When high speeds (or the amount of traffic flow) on the main road do not allow safe traffic joining / crossing for vehicles from the approach roads;
- Where a signalized intersection is not working properly / doesn't fulfill the expectations;
- Is the temporary solution part of a process for proving the appropriateness of constructing a roundabout as long-term solution;
- As a measure of traffic-calming.

Time period of usage of the assembled roundabout as a temporary solution

A temporary design solution implies a period during which:

- Traffic conditions are changed;
- Traffic flow is disturbed;
- Experiments for proving the suitability of constructing a roundabout as a permanent solution are conducted;
- A roundabout is being constructed as a permanent solution;
- The period from the time of deciding that the roundabout is a better solution than the existing solution, in terms of traffic safety or capacity, to the time of constructing the permanent solution.

Initially in Slovenia, assembled roundabouts were really temporary solutions, which were assembled for no more than a few weeks (or max. one to two months). Later (in 2007), a case-study, we accomplished an assembled roundabout on a national road in Slovenj Gradec (Figure 3) which was firstly to remain during the winter. There was namely a reasonable doubt about winter maintenance (snow ploughing) at assembled roundabouts, especially due to light elements from which roundabout was constructed. However, according to our experiences, the assembled roundabouts didn't present any important "obstacles" for winter conditions / maintenance - at least not in Slovenia.

Today, according to our experiences, assembled roundabouts in Slovenia could remain and are in function for much longer than just a few months. We have cases (for example in Maribor) when the assembled roundabout has remained functional for more than three years. Today's practice in Slovenia is, that assembled roundabouts remain functional till the construction of a roundabout as permanent (long term) solution - which could be from a few months to even few years.



FIGURE 3 First assembled roundabout on national road in Slovenj Gradec, year 2007 [2].

Processes prior to the construction of an assembled roundabout

All stages or processes before the construction of assembled roundabout are - more or less - identical, if we construct roundabouts as permanent solutions. The process consists of three phases: (a) verification of the appropriate conditions for assembled roundabout's construction, (b) the design of the assembled roundabout and (c) assembled roundabout's construction.

Verification of the appropriate conditions / criteria for an assembled roundabout is exactly the same as in the case of roundabouts as permanent solutions. Different countries use different criteria for assessing the justifications for implementation a roundabout. In Slovenia the following eight criteria are important:

- Functional criterion;
- Spatial criterion;
- Capacity criterion;
- Design (technical) criterion;
- Traffic-safety criterion;
- Front and Rear criterion – criterion of mutual impact of consecutive intersections;
- Economic criterion;
- Environmental and aesthetic criterion.

The process of designing the assembled roundabout is identical as roundabout design - or even slightly more complex, as it is necessary to take into account "the human factor". Namely, we must take into account the "accustoming" of users to previous solution.

Elements for assembled roundabout construction

The assembled roundabout can be constructed from different prefabricated elements (Figure 4), such as:

- Concrete prefabricated elements segment formats / shapes (for the construction of a central island);
- Prefabricated curbstone for the leading edge;
- Prefabricated (plastic) security fences.



FIGURE 4 Prefabricated elements for the construction of assembled roundabouts.

Design consideration for assembled roundabout implementation

According to our experiences with assembled roundabout design in Slovenia we could stress following design considerations:

- Design vehicle (trucks, buses, emergency vehicles) selection;
- Entry path deflection;
- Adequate path alignment (normally checked using a CAD-based vehicle turning path program);
- Crossings for pedestrians and cyclists;
- Ensure street lightening (if it is not already settled).

MINI ROUNDABOUTS

Mini-roundabouts are small roundabouts with a fully traversable central island. They are most commonly used within low-speed urban environments with average operating speeds of 50 km/h or less. They can be useful in such environments where conventional roundabout design is precluded by right-of-way constraints. In retrofit applications, mini-roundabouts are relatively inexpensive because they typically require minimal additional pavements at the intersecting roads and minor widening at the corner curbs. They are mostly recommended when there is insufficient right-of-way to accommodate the design vehicle with a traditional single-lane roundabout. Because they are small, mini-roundabouts are perceived as pedestrian-friendly with short crossing distances and very low vehicle speeds on approaches and exits. A fully traversable central island is provided to accommodate large vehicles and serves one of the distinguishing features of a mini-roundabout. The mini-roundabout is designed to accommodate passenger cars without requiring them to traverse over the central island. The overall design of a mini-roundabout should align vehicles at entry to guide drivers to the intended path and minimize running over of the central island to the extent possible [4].

In Slovenia we implemented the first mini roundabout in the year 2002. Since then we have build's more than 20 mini roundabouts across the country.



FIGURE 5 Typical Slovenian mini-roundabout (Maribor, 2013).

Proper design parameters of mini roundabout

When deciding to construct a mini roundabout it is necessary to consider the characteristics of the existing road network in the surrounding area (e.g. existing types/designs of intersections, etc.), the existing ways of traffic routing and the "expectations of users", i.e. traffic participants.

Mini roundabouts can be constructed instead of the existing "classic" three- and four-lane intersections, which can lead to a reduction in the number of traffic accidents, a reduction in delays and queues at the intersection, as well as reduction in the speeds of motor vehicles (as an individual traffic calming measure or combined with other traffic calming measures).

Mini roundabouts can be constructed only on those roads within settlements where the maximum allowed speed is 50 km/h (or lower). In addition, the measured speed V_{85} on joining roads of a mini roundabout (within the distance of 70 m from the mini roundabout) is lower than 50 km/h. If the measured speed V_{85} on joining roads exceeds 50 km/h, it is necessary to construct a mini roundabout together with other traffic calming devices and measures.

A mini roundabout is a good solution when reconstructing existing intersections (and as a "rehabilitation measure") within different environments – built-up areas, residential areas, business areas or shopping areas. Mini roundabouts are also suitable when reconstructing existing intersections:

- Intersections of "irregular shape" such as, e.g. Intersections in the shape of the letters "Y", "K", "A" and "X";
- Intersections in the shape of letters "F" and "H" (two consecutive "T" intersections within a short distance);
- When the traffic loads are approximately equal in the main and minor traffic routes;
- Where the installation of traffic-lights is not justified, but the capacity of an intersection with no traffic-lights is exceeded;
- When the main traffic route is unsuitable in relation to the existing intersection geometry.

Mini roundabouts are not the most suitable solution when the share of large motor vehicles in the main route is large (freight vehicles and/or buses). The construction of mini roundabouts is not recommended on significant public transport lines, in industrial/manufacturing zones, etc.

Design and construction elements of mini roundabouts

Designing a mini roundabout is done following steps similar to those when designing a classic roundabout. The designing is carried out in the following steps:

- Outer diameter;
- Width of the circular carriageway;
- Width of the carriageway in front of the roundabout;
- Width of the roundabout inbound point;
- Flare of the inbound point;
- Inbound radius,
- Inbound angle;
- Width of the roundabout outbound point;
- Outbound radius;
- Horizontal and vertical routing;
- Cross slopes and drainage;
- Other elements;
- Visibility;
- Equipment;

- Landscaping.

The following should also be taken into consideration when designing:

- Visibility and recognition of the mini roundabout. For mini roundabouts, it is important that drivers recognize the intersection in a timely manner and drive through it correctly. They must be designed in such a way that they enable vehicles to slow down in a timely manner, to stop if needed, and then continue driving safely. Drivers must be discouraged from drive improperly through the implementation of the right dimensions;
- The speed of vehicles: mini roundabouts are not designed for high speeds since – in terms of their elements - they consequently slow down traffic. The expected speed of vehicles is up to 25 km/h;
- Road characteristics;
- AADT;
- Number of branches;
- Traffic structure;
- Other traffic participants;
- Joining roads, noise and vibrations.

Splitter islands design

Splitter islands can be constructed in the following way:

- In de-levelled form / raised splitter island: edged splitter islands, where the splitter island must be at least 1.2 m wide at its narrowest point - installation of traffic signs (Figure 6);
- Splitter island constructed in the same way as the central island – as a mountable cobblestone island; the edge de-levelled by 3 cm (Figure 7);
- Splitter island made only with horizontal road signs / pavement markings.

According to our experiences it is desirable to construct - if it is possible - raised splitter islands at main traffic directions. With such solutions we could separate traffic moving in opposite directions, deflect entering traffic, prevent overtaking in the area of mini-roundabout and to provide opportunities for pedestrians to cross in two stages.



FIGURE 6 Raised splitter island at mini-roundabouts.



FIGURE 7 Splitter island constructed in the same way as the central island.

Traffic safety analysis of Slovenian mini roundabouts

Data and conclusions:

- we analyzed 11 mini roundabouts, which were built in the last 10 years in Slovenia;
- we performed B-A analysis of traffic accidents (TA). Period - 3 years before, 3 years after reconstruction;
- Only Police recorded accidents were included;
- in 11 mini roundabouts there was 15 TA before, only 2 TA after the reconstructions.

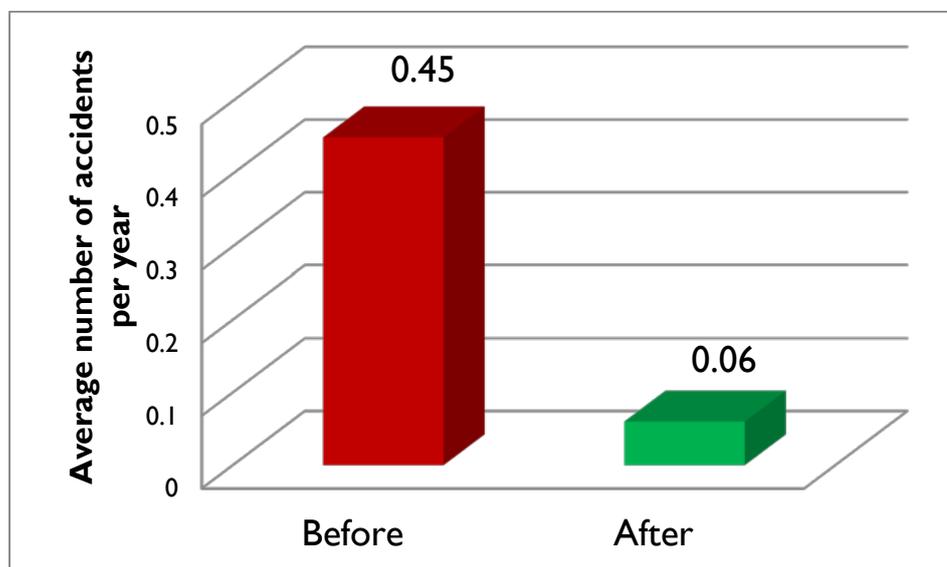


FIGURE 8 Average number of traffic accidents before and after reconstructions of intersections to mini roundabouts

SUMMARY AND CONCLUSIONS

This article presents the main findings from the analyses of implemented mini roundabouts and assembled roundabouts on Slovenian roads. These types of roundabouts are a relatively new roundabout design solution on Slovenian roads. Because of the fact that our research group - under the leadership of prof. Tomaž Tollazzi - at the Faculty for Civil Engineering, University of Maribor, was involved from the beginning in the process of implementing mini roundabouts and assembled roundabouts in Slovenia, we gained a lot of experiences and research results, which are presented in the article.

When implementing different possible types of assembled roundabouts, special consideration should be given to (a) Conditions and locations of appropriate use of the assembled roundabouts, (b) Time period of usage of the assembled roundabout as a temporary solution, (c) Processes prior to the construction of an assembled roundabout, (d) Elements for assembled roundabout construction and (e) Design consideration for assembled roundabout implementation.

Mini roundabouts, on the other hand, are not such a novelty - even in Slovenia. We using mini roundabouts as a roundabout design solution as a means of improving capacity and reducing delays at existing junctions where there is limited space to introduce other forms of control (or typical one lane roundabout). It is worth to mention that mini roundabouts in Slovenia today are also recognized as very efficient traffic calming measures inside built-up areas.

In Slovenia we implemented the first mini roundabout in the year 2002. Since then we have built more than 20 of mini roundabouts across the country. In this article we focused on (a) Proper design parameters of mini roundabouts, (b) Design and construction elements of mini roundabouts and (c) Splitter islands design.

From our experiences with mini roundabouts and assembled roundabout`s implementations, which we have obtained over the last 10 years, we already prepared a proposal for the updated version of a Slovenian technical specification about roundabouts design.

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